Innovation in Australian Enterprises:

Evidence from the GAPS and IBIS Databases*

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Abstract

This paper investigates the data relating to innovation in three databases: the Growth and Performance Survey (GAPS), the IBIS-Innovation Scoreboard and the Australian Workplace Industrial Relations Survey. The two databases we focus upon are the GAPS and IBIS. Data in GAPS includes questions on whether an innovation had occurred and on expenditures relating to innovation. The IBIS database contains R&D expenditures and the number of applications for patents, trade marks and designs for large Australian firms. Various summary statistics are presented and the data are analysed with reference to industry, firm size, firm age and foreign ownership categorisations. A number of broad results emerge. The extent of innovations (an output) and innovative activities (inputs) varies substantially across industries. For manufacturing firms the following points emerge. R&D and 'tooling-up' expenditures are the largest types of innovation expenditures. Small firms are much less likely to undertake R&D, although, those that do, tend to have high R&D intensities. The distribution of innovation intensities (e.g. R&D/sales) is skewed to the right (i.e. there are a small number of high intensity firms that can dominate). R&D intensity for individual firms appears to be volatile over time, with firms with the highest levels of R&D intensity tending to have the highest volatility.

Key words: innovation, R&D, intellectual property, firm performance

Working papers from the 'Performance of Australian Enterprises' project

Title	Number	Author(s)
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The Definition and Measurement of Productivity	9/98	Rogers
The Definition and Measurement of Innovation	10/98	Rogers
Innovation in Australian Enterprises: Evidence from GAPS and IBIS databases	19/98	Rogers
Productivity in Australian Enterprises: Evidence from GAPS	20/98	Rogers
Profitability in Australian Enterprises: Evidence from IBIS	21/98	Feeny/Rogers
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1. Introduction

This paper is concerned with the extent and nature of innovation in Australian firms. Measuring innovation is a difficult task due to the wide range of activities that can be considered to be innovative. Innovation can be defined as the application of new ideas to create added value for the firm or its customers. This is a wide definition and it implies that complete measures of the inputs and outputs of the innovation process will never be fully possible. The theoretical issues of defining innovation are discussed at more length in the predecessor to this paper (Rogers, 1998a) and we do not dwell on them here. In this paper we provide an empirical overview of the innovation data that are available.

This paper considers three databases, each of which provides evidence on different aspects of innovation. The two main databases are the ABS Growth and Performance Survey (GAPS) and the IBIS-Innovation Scoreboard database. The 1994/95 GAPS is a survey of around 9,000 private sector firms in a range of industries. The IBIS-Innovation Scoreboard database contains around 2,800 large firms for the period 1994 to 1996 (which is the time period considered here). The third database is the Australian Workplace Industrial Relations Survey (AWIRS) which contains around 2,000 workplaces in 1995.

The central aim of this paper is to consider the innovation related variables in these databases and to provide some preliminary analysis. The paper does not aim to investigate specific issues, such as the determinants of innovation or the effects of innovation on performance. These interesting and complex issues will be tackled in future work. This paper can be thought of as describing the "raw material" of innovation measures. Understanding how we can measure innovation, and the nature of the variables we have to work with, is of fundamental importance before we enter more complex analysis.

The structure of the paper is as follows. The subsequent section considers the GAPS database and the questions it contains relating to innovation. This database has been the subject of a number of recent studies (Industry Commission/DIST, 1997, Dept. of Workplace Relations and Small Business, 1997, 1998). This paper tries to avoid duplication by using different methods of analysing the data. Section 3 is concerned with the IBIS-Innovation Scoreboard (IBIS) database. The IBIS data can be used to assess the level of R&D effort and use of the intellectual property system by large Australian firms. Section 4 takes a brief look at some of the questions in the AWIRS database. The weakness of this database, for our purposes, is that the unit of observation is the workplace. For this reason, and given space considerations, we do not fully cover the potential data available in this database. A strength of the AWIRS database is that the survey questions cover areas of innovation such as managerial and organisational change. The final section draws some broad conclusions from the analysis.

2. The Growth and Performance Survey (GAPS)

2.1. Introduction

The GAPS survey (also known as the Business Longitudinal Survey) was first conducted in 1995 and collected data on the financial year ending 30 June 1995, or the firm's closest financial period. The GAPS covers a representative sample of Australian firms, although a number of firm types and industry sectors are excluded from the sample. The excluded groups include non-employing firms, all government enterprises and the following industry sectors: agriculture, forestry and fishing; electricity, gas and water; communication services; government administration and defence; education; and a number of other smaller industry codes (see Industry Commission/DIST, 1997, p. 5). The survey covers almost 9,000 firms and is designed to allow estimates of the entire population of Australian firms (for those firms not explicitly excluded from the survey). To achieve this, the survey design used a stratification based on both industry and employment size classification. The ABS have developed a set of weights based on the sampling technique and the population frame (taken from the Business Register), and we use these weights in this paper.[1] In this paper we do not discuss in detail the accuracy of the population estimates presented. In general, the standard error for an estimate of a proportion is given by

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[1] Further details of the survey method can be found in Industry Commission/DIST (1997) and a paper by the ABS presented at the SEAANZ 1997 conference.

$$se \quad \sqrt{\frac{p(1-p)}{n}}\sqrt{\frac{N-n}{N-1}}$$

where p is the proportion, n is survey size and N is the population size. As an example, the estimate of the proportion of innovators from the sample is 8.5%; using the above formula the 95% confidence interval (a two s.e. range) is 8.1% to 8.9%.

The 1994/95 survey contains a number of questions about the extent of innovation. These were included at the end of a relatively large survey form (the questions numbers are 65 and 66). The questions asked are different for manufacturing and non-manufacturing firms. Non-manufacturing firms are asked only about whether innovation had taken place. Manufacturing firms are asked both about completed innovations and also about expenditures on innovation related activities. The innovation activities considered are R&D, acquisition of technology, training, tooling-up and marketing expenditures. For the last three categories, the survey asked for only the expenditure that related to the development of new products or processes.

Table 1 details the questions asked about completed innovations. We use these questions to define the category of 'innovators' (i.e. the firms that answered 'yes' to these questions). Table 2 details the questions concerning innovation related expenditures which were only included on the survey sent to manufacturing firms.

Table 1 Questions concerning innovation(s) introduced in GAPS

	Question *YES / NO response required*
Question to manufacturing firms	Did this business in the last financial year develop any new products or substantially changed products or introduce any new or substantial changed processes
Question to non-manufacturing firms	Did this business in the last financial year introduce any new services or significantly change ways of delivering existing services, or introduce any new or substantially changed goods[2]

Table 2 Questions concerning innovative activities (manufacturing firms only)

Category	Questions *What was the estimated expenditure on the following categories?*
R&D	R&D performed by this business and payments to others for R&D (exclude R&D done purely as a service to others)
Training	Training of staff associated with the development of new or changed products or processes
Acquisition of technology	Acquisition of patents, trade marks and licences
Tooling-up	Expenditure associated with machinery, equipment or buildings to improve production or produce new/changed products
Marketing	Expenditure associated with new or changed product

[2] On the actual survey this question was asked in two parts. First, whether any new services or significantly changed ways of delivering existing services had been introduced and, second, whether any new or substantially changed goods had been introduced. In this paper we have combined the responses so that a 'yes' answer to either question means the service firm is an 'innovator'.

2.2. *The proportion of innovators*

This section considers the proportion of firms that can be classified as innovators. Using the results from the entire survey, we find that 8.5% are innovators (in the sense defined by the questions in Table 1 above). An obvious question is what are the characteristics of these innovators and, in particular, what are the significant differences between innovators and non-innovators. In this paper we provide a preliminary analysis of this issue by considering the proportion of innovators in different industries and firm sizes. In addition, we consider whether the proportion of innovators varies with the extent of foreign ownership in the firm and with the age of the firm. Needless to say, they are a wide variety of other firm characteristics that we could also consider (e.g. profitability, productivity, export status, the level of competition faced, etc). These characteristics will be the source of future research.

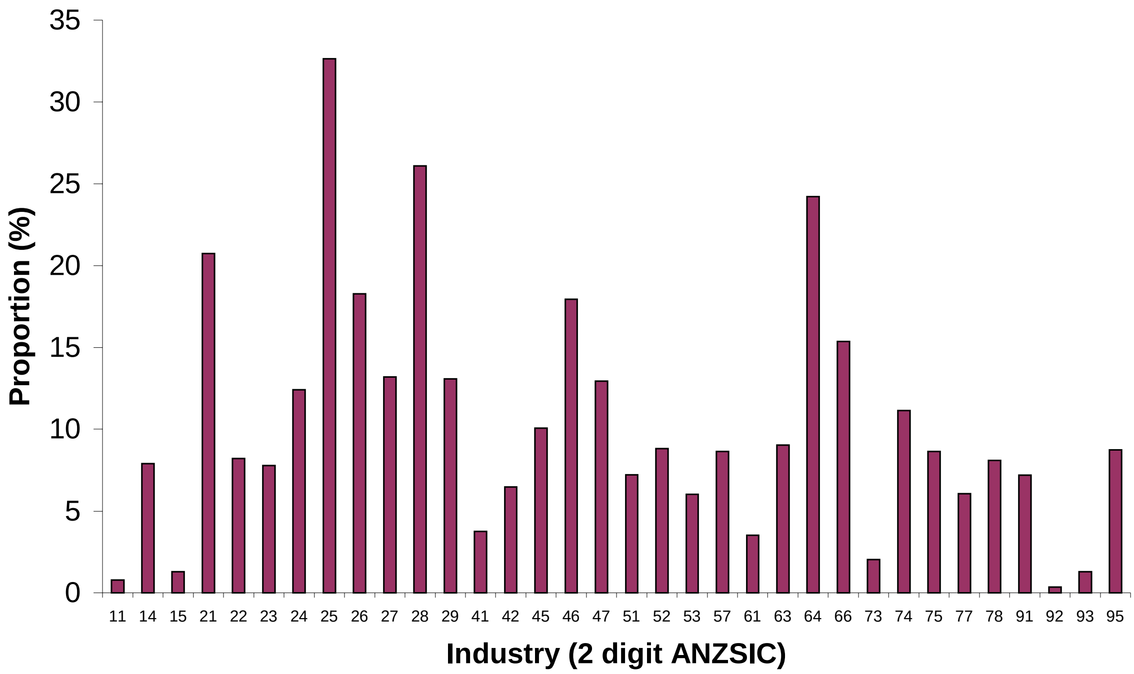
Differences across industries

In any analysis of a set of heterogeneous firms the researcher is aware that some of the firms may be exposed to similar external conditions (e.g. competition, technological opportunity). A common way to investigate these ideas is to look at differences between industries. If such differences exist they prompt consideration of the underlying factors that may cause the observed differences. Figure 1 below shows the proportion of innovators by industry (defined at the 2-digit ANZSIC level). The most striking feature of the figure is the large differences between industries. The industry with the highest reported proportion of innovators is 'Petroleum, Coal, Chemical and Associated Product Manufacturing' (ANZSIC 25), with 33% of firms responding 'yes' to the innovation question (see Table 1)[3]. At the sector level we find the proportion of innovators for manufacturing is 17%, while for non-manufacturing firms the figure is 8%. However, within the non-manufacturing sector they are some industries with relatively high reported rates of innovation. In particular, 18% for 'Machinery and Motor Vehicle Wholesaling' (46) and 24% for 'Air and Space Transport' (64). These results suggest that innovative activity is concentrated in a few

[3] The most recent ABS Innovation Survey (ABS, 1998) also finds that this industry has the highest rate (35%) of innovation among manufacturing firms.

industries and these are mostly, but not exclusively, in the manufacturing sector. The idea of a number of key industries driving innovation through the economy is not new. OECD (1996) and Papaconstantinuo (1996) discuss the importance of certain sectors in R&D expenditure and find that the top 5 industries in most countries account for 60-80% of all R&D expenditures. They also note that although the majority of innovations may be created in a small number of industries they are often used by a range of other industries.

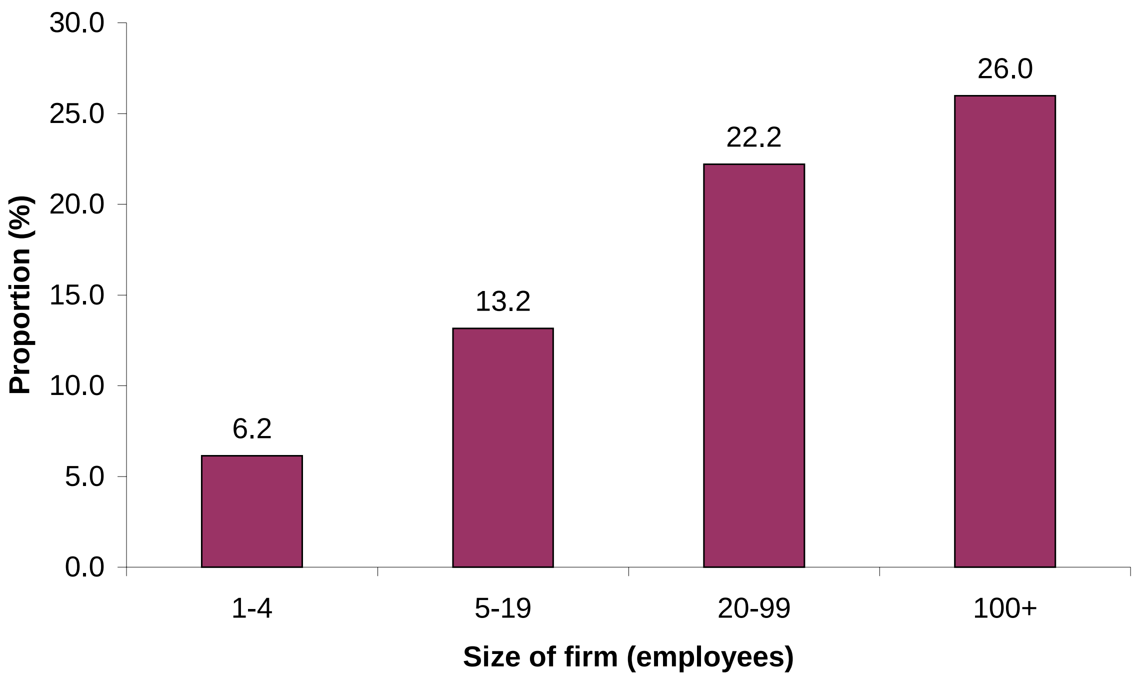
Figure 1 Proportion of innovators by industry



Differences by firm size

Investigation of the (possible) link between firm size and innovation has a long history. Joseph Schumpeter suggested that the innovation process would differ between small (entrepreneurial) firms and large (bureaucratic) firms. This has tended to lead to empirical analysis into the relationship, if any, of firm size and innovative effort or output (see Cohen and Levin, 1989, or Symeonidis, 1996, for a review). In short, they are no universal size-innovation findings. More generally, the potential size-innovation relationship reflects a variety of factors including: the ability to finance innovation, the ability to spread risk, the managerial quality of small and large firms and market power issues. Figure 2 below shows how the proportion of innovators varies by firm size. The four categories of firm size used (1 to 4 employees, 5-19, 20-99 and 100 plus) allow a focus on the 'small and medium enterprise' (SME) sector. The figure shows that the proportion of innovators increases with firm size. This may appear at odds with the view that the smallest companies are often the most highly innovative, however, it should be remembered that the GAPS surveys all types of SME's, not just 'high potential, high growth' SMEs. It should also be noted that the indicator of innovation used here is a 'yes/no' binary variable and not a measure of innovation intensity or effort. For example, small companies may devote considerable resources to introducing new products but, due to their size, they may introduce a new product every 2 years (hence, since the questions in Table 1 refer to the last financial year, they would respond 'no' to being an innovator in alternate years). A large firm may introduce a single new product each year, answering 'yes' to the innovator question, even though each new product may be the result of a small innovation effort.

Figure 2 Proportion of innovators by firm size



Differences by age of firm

Many researchers view the economy as a dynamic system with the forces of competition and cooperation leading to the growth and decline of existing firms and the entry of new firms. This 'evolutionary' view implies that the age of a firm may have some relationship to innovation (although, of course, this may only be revealed when a host of other factors are controlled for). The GAPS has a question concerning the age of the business allowing us to do some preliminary analysis. Figure 3 shows the proportion of innovators by 6 categories of age. To interpret this figure it is important to know that the survey question on age differs according to the legal status of the firm.[4] Where a firm is a public company or a trust the question is "how many years has this public company/trust been in operation". If the firm is any other type of incorporated company, a sole proprietorship, partnership or other category the question is "how many years has this business been owned/controlled by the present owner". For our purposes here this distinction may be important since one might expect a firm that has started in business in the last year to respond 'yes' to the question(s) in Table 1.[5] On the other hand, a change in ownership in the last year might well be associated with a 'no' answer (since no new or changed products or services may have occurred). This means that the 'less than 1 year category' is difficult to interpret clearly.[6] Focusing on the age groups above one year, Figure 3 shows that only the 1 to 2 year age category has a substantially different (lower) proportion of innovators. This may well be due to this age group having a greater share of small firms.

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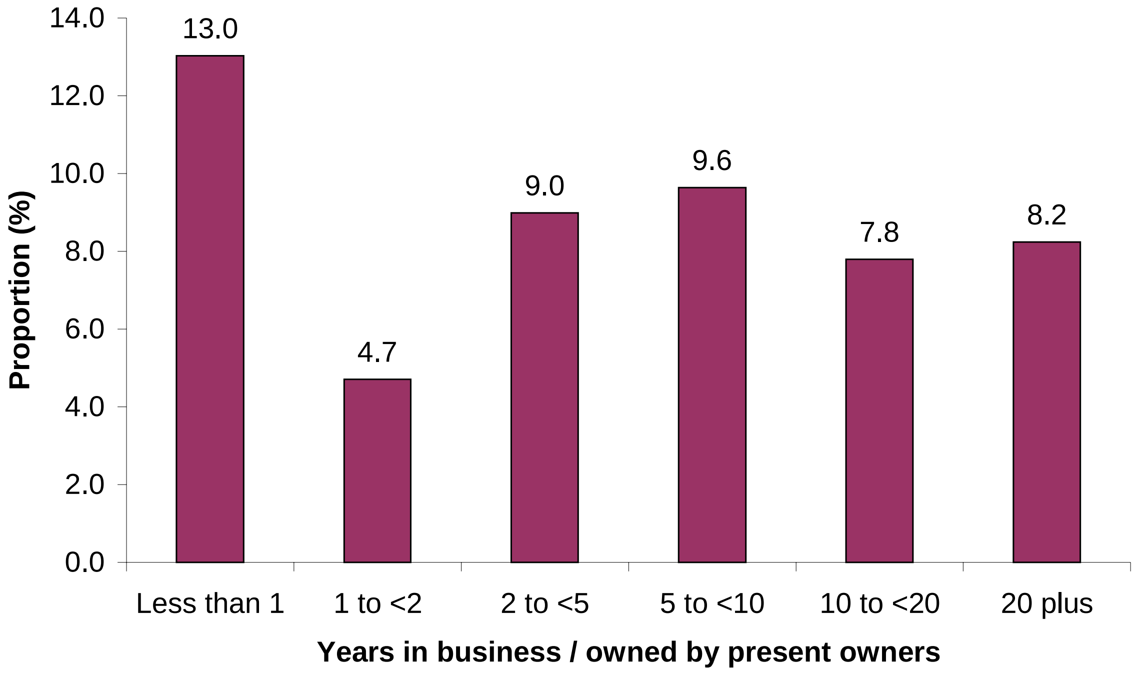
[4] In addition, the ABS did not ask the age of firm where they thought the information could be found in other ABS databases. This procedure did not allow full coverage of 'age' in the final data (see Industry Commission/DIST, 1997, p.8, footnote 1).

[5] The essential issue is whether starting a new firm is classified as innovative.

[6] The less than one year category also relies on the ABS Business Register (the population frame used for the GAPS) correctly tracking the birth of new firms. If the register under-represents some groups of new firms (possibly the smallest) then the GAPS will have under sampled these groups.

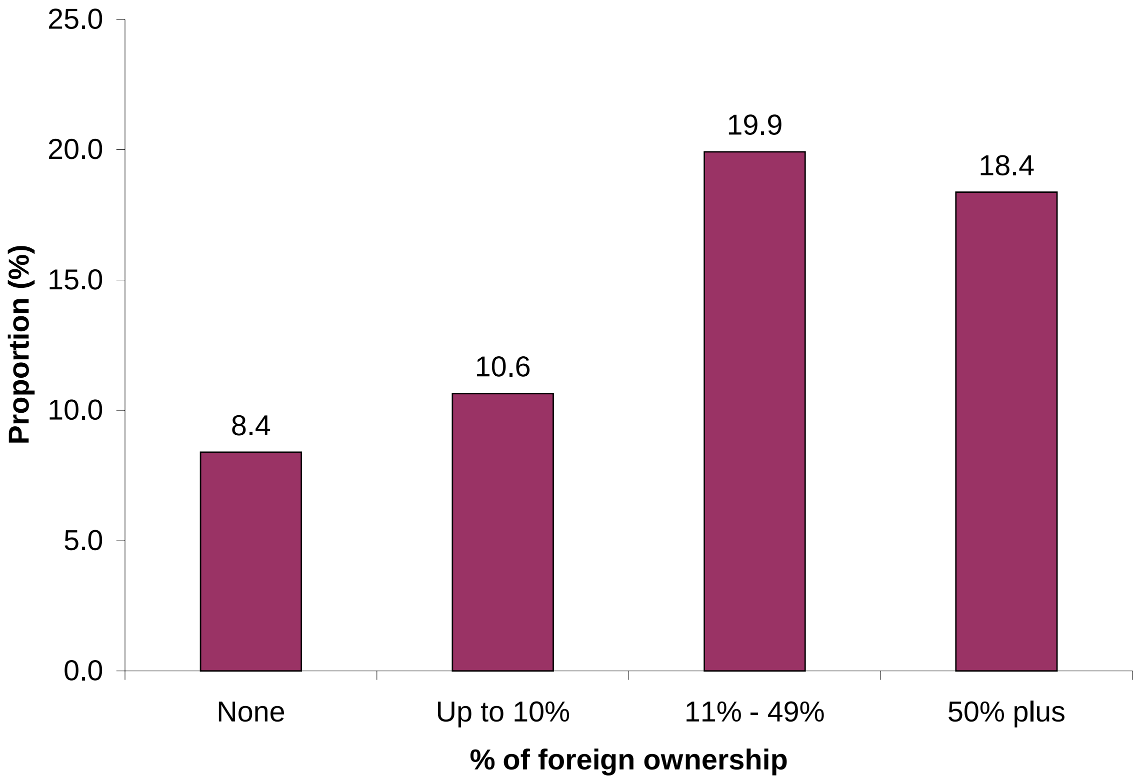
Figure 3 Proportion of innovators by firm age



Differences by foreign ownership status

Figure 4 below shows the proportion of innovators according to the share of foreign ownership. The GAPS questionnaire asked for respondents to select one of the following categories: no foreign ownership, up to 10%, 11%-49% and 50% plus. The figure shows that a foreign ownership stake of over 11% appears to be associated with a higher proportion of innovators. There may be a number of reasons for such an increase. First, a foreign shareholder may imply greater international exposure to market competition and, since competition may be a spur to innovation in certain situations (Symeonidis**,** 1996), foreign ownership may imply higher innovation. Such a mechanism can, of course, be tested more directly with information on the export status of the firm and the international nature of the domestic industry in which it sells its products. A second, theoretically separate reason for the innovation-foreign ownership link is that the knowledge, technology and/or finance is supplied by the foreign entity. If this is the case then foreign ownership should remain a important determinant even when international competition is controlled for. These are topics for future research on the Australia data (see Love et al, 1997, for a study of Scottish firms which confirms a positive innovation effect of foreign ownership). A third reason may simply be that foreign ownership is correlated with other firm characteristics such as firm size. It may also be that foreign investment tends to be concentrated in high technology and highly innovative sectors. Again, these are hypotheses that can be investigated in future papers.

Figure 4 Proportion of innovators by percentage of foreign ownership



2.3. Innovative activities (for manufacturing firms)

As discussed above, for manufacturing firms the GAPS asked a number of additional questions about innovation (see Table 2). These attempt to assess the financial resources devoted to various innovative activities.[7] Such activities may result in an "innovation" (as defined in Table 1) in the year covered by the survey. Alternatively,

[7] It should be noted that firms may experience difficulty in dividing expenditures into those relating to innovative and non-innovative activities. For example, although the overall marketing budget may be recorded, the share of this devoted to 'the launch of new or changed products' may not be known.

innovation activities carried out now may result in an innovation in the future. It is also possible (or perhaps likely) that many innovative activities do not result in a successful innovation. To analyse the responses to the questions in Table 2 we divide the expenditure by sales to form an intensity (e.g. R&D expenditure divided by total sales).

The following table shows summary statistics for the intensity measures calculated with all intensities expressed as percentages of total sales.[8] The major conclusion to be drawn from the statistics presented in the table is that the distributions for the various intensities are skewed to the right. This can be seen from comparing the maximum and mean of the variables. The R&D intensity variable, for example, has one firm reporting a R&D intensity of 1,035% whereas the mean is 0.15%. The high values for the various maximums may be due to survey error (for example, a firm might have entered R&D in dollars not realising the question was asked in terms of thousands of dollars). However, it is also possible that some firms may have intensities exceeding 100%. These firms may be in the start-up phases of business and hence are investing heavily in new technology and general development (e.g. new biotechnology companies).

Table 3 Summary statistics for innovation intensity

Variable	Mean	Std. d	Min	Max
		Percentages		
R&D / sales	0.15	6.97	0	1,035
Training / sales	0.01	1.14	0	200
Acquisitions / sales	0.0038	0.251	0	77.6
Marketing / sales	0.035	1.61	0	250
Tooling-up / sales	0.074	2.37	0	376

[8] 'Sales' is defined as income during the year less the difference between closing and opening stocks and, strictly, corresponds to a measure of real output not sales.

Looking at the means in Table 3 they suggest that R&D has the highest intensity, followed by 'tooling-up', marketing and then acquisition of technology. Since the mean will be influenced by the presence of outliers, this ranking should not be given too much emphasis. An alternative method of assessing the relative importance of each category would be to sum the expenditures on each activity across all firms. This was done in Industry Commission/DIST (1997, Table 3.249) and shows that the largest category of expenditure is tooling-up with 41.7% of all innovation expenditures, R&D is next with 41.3%, followed by marketing (11.3%), acquisition of technology (3.2%) and training (2.5%).

Differences across industries

Table 4 shows the mean intensities of the various innovation intensities by industry. The table shows that R&D intensity and 'tooling-up' intensity always have a mean value higher than any other category of expenditure. Note also that in 4 out of the 9 industries the mean of the 'tooling-up' intensity is higher than the mean of R&D intensity. This again indicates that both R&D and tooling-up expenditures are important in the manufacturing sector.

Table 4 Mean of innovation intensity by industry

Industry (2 digit ANZSIC – see Table 5 for descriptions)	R&D / sales	Training / sales	Acquis-itions / sales	Market-ing/sales	Tooling-up / sales
			Mean values (percentages)		
21	6.265	0.035	0.008	0.434	0.572
22	0.123	0.044	0.002	0.031	0.173
23	0.182	0.002	0.000	0.060	0.138
24	0.365	0.061	0.005	0.270	0.594
25	1.608	0.031	0.021	0.171	0.778
26	0.403	0.067	0.022	0.300	0.807
27	0.436	0.138	0.026	0.204	0.660
28	3.178	0.405	0.085	0.680	1.494
29	0.340	0.029	0.000	0.119	0.352

Table 5 presents the data in a different way by using the percentages of firms with non-zero R&D, and also the percentages of firms with high R&D intensity (defined as greater than 1% of revenue). This avoids the problems of extreme values affecting the mean value.

Table 5 Percentage of firms with non-zero and high R&D intensity

Industry (2-digit ANZSIC)	% of firms with R&D intensity greater than 0%	% of firms with R&D intensity greater than 1%
Food, Beverage and Tobacco (21)	19.6	8.3
Textile, Clothing, Footwear & Leather (22)	6.1	3.6
Wood and Paper Products (23)	2.8	1.7
Printing, Publishing and Recorded Media (24)	10.2	5.4
Petroleum, Coal, Chemical Products (25)	41.1	22.9
Non-Metallic Mineral Products (26)	15.3	8.2
Metal Products (27)	10.2	5.4
Machinery and Equipment (28)	26.4	20.9
Other Manufacturing (29)	11.1	7.0

A further method of analysing the data is to calculate the ratio of R&D expenditures to non-R&D innovation expenditures (i.e. the latter calculated as the sum of marketing, acquisitions, training and tooling-up). This ratio is an indicator of the relative importance of R&D in overall innovative effort. In a similar way we can also calculate the ratio of all training expenditures to those training expenditures relating solely to innovation (since the GAPS asks a question on total training expenditure as well as the training question in Table 2). The mean values for both these ratios for separate industries are shown in Table 6. Industries with high mean ratios for R&D to non-R&D expenditures are 22, 27, and 28, implying that R&D is relatively more important in these industries. A low value for the ratio, such as in printing and publishing (23), indicates that other innovation expenditures apart from R&D are important. These results once again confirm that the nature of innovation varies across industries.

Table 6 Importance of R&D and training ratios, by industry

Industry	Mean of ratio of R&D to non-R&D expenditures	Ratio of 'innovation-related training' to all training
Food, Beverage and Tobacco (21)	2.0	0.12
Textile, Clothing, Footwear & Leather (22)	3.4	0.09
Wood and Paper Products (23)	1.7	0.03
Printing, Publishing and Recorded Media (24)	0.9	0.07
Petroleum, Coal, Chemical Products (25)	1.7	0.12
Non-Metallic Mineral Products (26)	0.8	0.11
Metal Products (27)	2.8	0.13
Machinery and Equipment (28)	2.9	0.27
Other Manufacturing (29)	1.6	0.33

Differences by firm size

Table 7 below shows the mean values of some of the innovation intensities (we omit training and acquisition of technology, the lowest expenditure categories). Considering the mean of R&D intensity, note that, apart from the very smallest firm size category, R&D intensity is approximately constant at around 0.2%. This is somewhat surprising given the data on innovators shown in Figure 2. Part of the reason for this is the skewed distribution of small firms R&D. For example, the firm with the R&D intensity of 1035% is in the 1-4 employees firm size category, which will raise the mean substantially. Table 8 shows the percentage of firms with non-zero R&D intensity and also with R&D intensity over 1%. This shows that while the 1-4 firm size category has substantially less firms doing R&D, almost all of these (90%) are high R&D intensity firms. In contrast, for the largest firm size category (100 plus employees), although 16% are doing R&D only a third of these are high R&D intensity firms.

Table 7 Innovation intensity by firm size

Firm Size *employees*	R&D / sales	Tooling-up / sales	Marketing/ sales	Mean of ratio of R&D to non-R&D expenditures	Ratio of 'innovation-related training' to all training
1-4	0.12	0.07	0.04	1.31	0.01
5-19	0.22	0.08	0.02	2.16	0.02
20-99	0.21	0.18	0.09	1.84	0.08
100+	0.19	0.14	0.04	7.43	0.07

Table 7 also shows that smaller firms tend to have lower 'tooling-up' to sales intensities and lower ratios of R&D to non-R&D expenditures. The latter ratio shows a distinct jump to 7.4 for the largest firm size category. This implies that smaller firms devote larger *relative* amounts of innovation related expenditure to non-R&D activities. In other words, given a set budget for innovation, smaller firms tend to spend less on R&D as commonly defined and more on other activities. This could be due to a variety of reasons including: the nature of smaller business requires relatively more to be spent on, say, marketing; or, smaller firms do not allocate expenditures to a specific R&D account while large firms do (perhaps due to tax considerations).

Table 8 Percentage of firms with non-zero and high R&D intensity

Firm size *employees*	% of firms with R&D intensity greater than 0%	% of firms with R&D intensity greater than 1%
1-4	0.6	0.57
5-19	1.9	1.16
20-99	8.1	3.90
100+	15.8	5.29

Differences by age of firm

Table 9 shows the means of the various intensities and ratios discussed above. Considering R&D intensity, the table shows that the 1 to 2 year age group has the highest intensity. Table 10 shows the percentages of firms that undertake R&D and those that have an R&D intensity greater than 1%. Here again we can see that the 1 to 2 year age group has the largest percentage of high R&D intensity firms (1.07%), which is the likely cause of the high mean value in Table 9. Note that this result contrasts with the results in Figure 3 which suggested that this age group had low levels of innovators. The table also shows that the oldest age category, although having the largest proportion of firms undertaking R&D, also has the lowest share of these as high R&D intensity firms (around 50% of firms in this age group that do R&D have a R&D intensity above 1%).

Table 9 Mean innovation intensity measures by age of firm

Age of firm *years*	R&D / sales	Tooling-up / sales	Marketing/ sales	Mean of ratio of R&D to non-R&D expenditures	Ratio of 'innovation-related training' to all training
Less than 1	0.19	0.01	0.09	0.45	0.00
1 to <2	0.55	0.10	0.14	1.82	0.03
2 to <5	0.18	0.12	0.03	1.69	0.01
5 to <10	0.08	0.07	0.02	3.01	0.02
10 to <20	0.08	0.06	0.01	2.10	0.04
20 plus	0.05	0.04	0.02	1.85	0.04

Table 10 Percentage of firms with non-zero and high R&D intensity

Age of firm *years*	% of firms with R&D intensity greater than 0%	% of firms with R&D intensity greater than 1%
Less than 1	0.97	0.69
1 to <2	1.29	1.07
2 to <5	1.16	0.84
5 to <10	1.42	0.99
10 to <20	1.20	0.72
20 plus	1.97	0.97

3. Large Australian firms: R&D and intellectual property

3.1. Introduction

The IBIS large firm database contains financial data on around 2,800 large firms in Australia in the 1993 to 1996 period (Feeny and Rogers, 1998, discuss the IBIS data in more detail). The IBIS database, which contains R&D data for a sub-set of firms, has been combined with data on the applications of patents, trade marks and designs for the 1996 calendar year. Thus, there are two proxies for innovation that we can analyse – R&D and intellectual property applications. These are considered in the next two sections. Before this, Table 11 shows details of the size of the firms under consideration. The table shows summary statistics for 138 non-government firms that have an R&D expenditure figure in each of the years 1993 to 1996. The indicators of size are total revenue and number of employees the data refer to the average of these variables over the 1993 to 1996 period. The mean size of firms considered in this section is large, with even the smallest of firms tending to fall in the largest category (100 plus employees) considered in the last section.

Table 11 Summary statistics for size of firm

Variable	Mean	Median	Standard Deviation	Minimum	Maximum	5th percentile
Total revenue ('000s dollars)	862,777	226,978	2,223,269	26,463	18,005,600	37,933
Employees	4,097	1,010	10,629	70	77,220	175

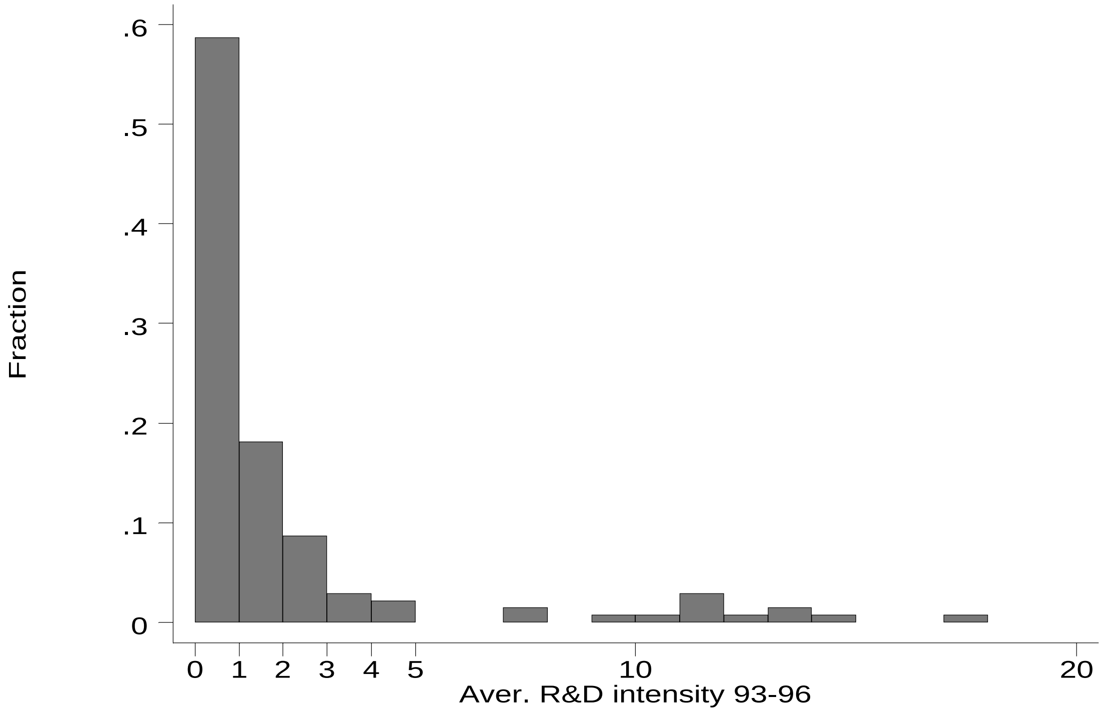
R&D data

R&D data in the IBIS database comes from a variety of sources including published accounts, the ASX and direct surveys of firms by IBIS. It is important to note that there is no requirement for firms to report R&D expenditures. This means that the IBIS database is unlikely to provide an unbiased sample; firms that wish their

R&D expenditures to remain secret will not appear. Since such firms may be highly innovative this is of concern. It should be noted that the overall total of R&D expenditures considered here is large. The 138 firms defined above have a combined R&D spend of $1.5 billion. In comparison, the ABS estimates that a total of $4 billion was spent on R&D by the Australian private sector in 1995-96 (ABS, 8104.0). Since the IBIS database has a much greater coverage of large firms, a more appropriate comparison would be the ABS estimate of R&D expenditure by large firms. For firms with over 1000 employees the ABS estimates R&D expenditures of $1.5 billion, while firms with over 1000 employees in the 138 firm sample have a total R&D spend of $1.2 billion. For large firms, therefore, the IBIS R&D data has a relatively high coverage.

Using the IBIS data we again construct R&D intensity (R&D / total revenue). As became apparent in the GAPS data, R&D intensities tend to be positively skewed. Figure 5 shows a histogram of the 138 firm sample (the distribution of the average R&D intensity over the period 1993 to 1996 is shown) and this feature can be clearly seen in the IBIS data. Almost 60 percent of firms have a R&D intensity below 1% but the range of intensities rises to close to 20%. By way of comparison, for the 100 plus employee group in the GAPS, 57% of the firms that undertook R&D had intensities below 1%.

Figure 5 Histogram of R&D intensity (138 firm sample)

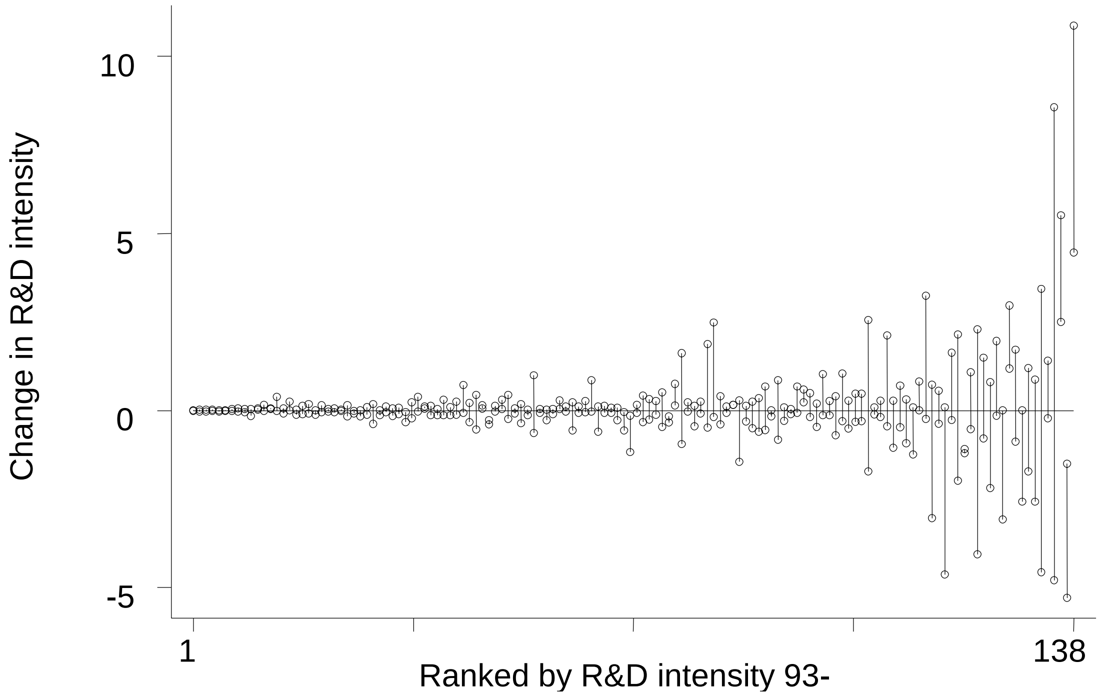


A second important feature of the R&D data, which we could not investigate using GAPS, is that the R&D intensities of firms varies over time, especially for firms with high R&D intensity. Figure 6 depicts one method of showing this. Prior to graphing the figure the change in year on year R&D intensity is calculated for each firm (i.e. if R&D intensity moved from 5% in 1993 to 7% in 1994, the change is 2%). Each vertical line represents a firm, with the firms ordered by average R&D intensity (93-96) from left to right (with the highest average R&D intensity firm being represented by the far right vertical line). Each vertical line joins the maximum and minimum changes in R&D intensity for that particular firm. Hence, a long vertical line represents relatively large changes in intensity. If the line extends below zero on the y-axis then R&D intensities have fallen at some point. The figure shows that R&D intensities are volatile, with the volatility appearing to increase with the average level of R&D intensity. Note also that falls in R&D intensities are relatively common (i.e. many of the vertical lines extent below the horizontal axis).

Volatility in R&D intensities would be expected if firms have "lumpy" R&D projects, implying that expenditures need to vary from year to year. Alternatively, highly R&D

intensive firms may experience cash flow problems that force expenditures to fall. The former reason is benign, the latter may be a cause for more concern if capital markets are, for some reason, not allocating funds to worthwhile R&D projects (see National Investment Council, 1995 for a discussion of innovation financing). This is an area that can be researched using subsequent GAPS data and IBIS data. It should also be noted that the volatility may result from firms failing to report R&D consistently over time, even though the underlying expenditures may have been constant. This would seem unlikely although it cannot be ruled out due to the lack of legal requirements to report R&D. In any event, both the skewness of the distribution of R&D intensity, and the year on year volatility, suggest that influential variables could be a problem in regression analysis.

Figure 6 Volatility of R&D intensity (1993 – 1996)



Intellectual property data

The data on intellectual property (patents, trade marks and designs) are for applications in the 1996 calendar year. These data are compiled by matching the names of firms in the IBIS database against IP Australia's *Annual Record of*

Proceedings, which is the complete list of all applications made or designated in Australia. The parent company name, and the names of all majority owned subsidiaries were checked against the *Proceedings*. Use of applications, not grants (i.e. successful applications) can be justified for two reasons. First, there can be lag of a few years before an application is granted, hence use of grants might provide an out of date assessment of a firm's current innovative activities. Second, since the use of the applications data is intended as a proxy for current innovative activities, and given that innovation is normally defined as ideas that are new to the firm, use of applications have some merit. This is because even if the application is unsuccessful due to the idea existing somewhere else, there is still an implication that the firm is making efforts to innovate. Obviously, it would be preferable to have data on both applications and grants to test such ideas, but creation of such databases are a costly and time intensive process.

Table 12 shows the percentage of these firms who made at least one IP application in 1996. The proportion of firms who spent a positive amount on R&D is also shown for reference. The last row in the table shows the percentage of firms having undertaken at least one of the activities. For all firms in the IBIS database this percentage is 26%; in comparison the GAPS data also found that 26% of firms with more than 100 employees were 'innovators'. This suggests that the joint use of R&D and IP data may yield a similar proxy for the number of innovators.

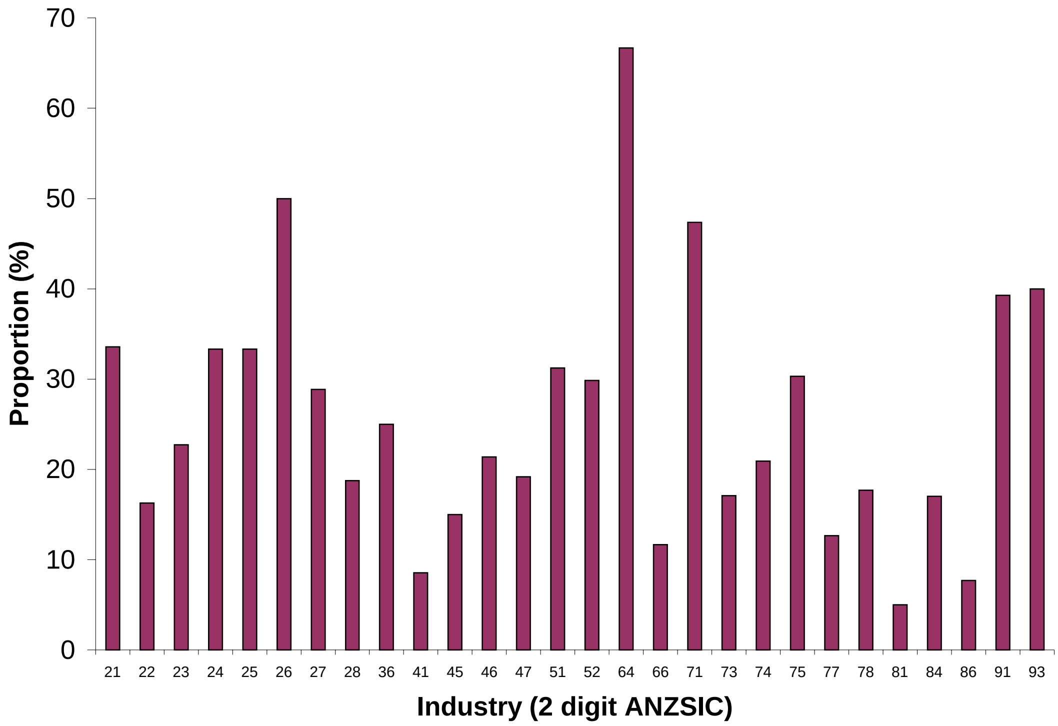
Figure 7 considers an industry breakdown of trade mark activity. The vertical scale shows the percentage of firms in the industry that applied for at least one trade mark (industries with fewer than 5 firms falling into this category were excluded). Air and space transport (64) shows the highest proportion (they are only 9 firms in this industry and 6 of these took out at least one trade mark application). In general, the figure conveys a similar message to Figure 1: innovative activity varies substantially across industries.

Table 12 Extent of IP and R&D activity

Innovation Activity	% of enterprises in IBIS undertaking activity	% of largest enterprises undertaking activity
R&D	11.6	19.2
Patent applications	4.5	8.2
Trade mark applications	17.6	31.0
Design applications	2.1	4.3
Any of above	25.9	42.7

Notes: Percentages based 2629 firms. Largest firms are those will total revenue exceeding $100 million.

Figure 7 Trade mark activity by industry (1996)



4. The Australian Workplace and Industrial Relations Survey

The Australian Workplace and Industrial Relations Survey (AWIRS) is another source of data on innovation. In this paper we will only consider a small sub-set of the AWIRS questions on innovation. A more detailed review can be found in Rogers (1998b). Part of the reason for not focusing more attention on AWIRS is that the data relates to workplaces not firms. Also, the phrasing of the questions tends not to match similar questions in GAPS. However, an advantage of the AWIRS data is that it covers a wider range of innovation related activities such as management and organisational change. The first column of figures in Table 13 shows the proportion of workplaces undertaking certain types of change over the last *two* years (note that this is different to the single year considered by the GAPS and IBIS data). The table shows that the proportions are often quite high, for example, over 50% of workplaces underwent a restructure of their organisation (which implies about 25% do so in a single year). Such change need not, of course, be innovative. The second question, concerning introduction of major new plant, etc, could be considered part of 'process innovation'. The table also contains a column for "small" workplaces, these are defined as those with less that 100 employees and whose parent firm has no more than 100 employees in Australia[9]. In general, as we found above, smaller firms experience slower rates of change, although they do appear more likely to introduce major new plant, machines or equipment.

[9] This somewhat clumsy definition is necessitated by the way in which AWIRS classifies workplaces.

Table 13 AWIRS questions concerning change (1995 general management questionnaire)

Which, if any, of the changes listed, happened at this workplace in the last two years		% of all workplaces	% of "small" workplaces
1)	Introduction of new office technology (not just routine replacement)	47.0	36.8
2)	Introduction of major new plant, machinery or equipment (not just routine replacement)	27.9	30.4
3)	Major reorganisation of workplace structure (e.g. changing the number of management levels, restructuring whole divisions/sections and so on)	51.5	44.1
4)	Major changes to how non-managerial employees do their work (e.g. change in range of tasks done, changes in type of work done).	42.7	36.9

5. Conclusion

The purpose of this paper has been to provide an overview of the databases, and variables within these databases, that can be used for work on innovation.[10] The variables considered include survey based questions on whether an innovation(s) had occurred, financial data on expenditures related to innovative activities and counts of intellectual property applications.

Survey based questions on whether an innovation had occurred over the last year provide a useful broad indicator of the extent of innovation. The drawback of such measures is that the 'yes' or 'no' response provides only a binary classification of innovators and non-innovators. Firms in the innovators category will have a wide range of innovation intensities. Bearing this drawback in mind, section 2 found that the proportion of 'innovators' varies dramatically across industries (defined at the two digit level). This should not be a surprise since it is recognised that innovation in the

[10] One major database not included here is the ABS Innovation Survey conducted in 1993/4 and 1996/7. Phillips (1997) provides an analysis of the 1993/4 data. Future research intends to utilise the recently available 1996/7 data.

economy is often driven by a small number of sectors. The results also suggest that the determinants of innovation may vary substantially across industries. The proportion of innovators is found to increase with firm size (Figure 2), although this result is likely to be partly due to the binary classification.

For manufacturing firms the GAPS contains data on expenditures on R&D, tooling-up, the acquisition of technology, marketing and training. These can be converted into intensity measures by dividing by sales, such intensities provide indicators of the level of innovative effort independent of firm size. R&D and tooling-up (expenditures on new machinery and associated costs) are the most important categories of expenditure. However, we again find that their relative importance varies across manufacturing industries (Table 4 and 5). Looking at variations between firm sizes, we find that the smallest manufacturing firms (1 to 4 employees) have the lowest mean R&D and 'tooling-up' intensity (Table 7). We also find that the smallest manufacturing firms have the lowest proportion of firms undertaking R&D (0.6%), whereas almost 16% of firms with more than 100 employees undertake R&D (Table 8). Although small firms appear not to use R&D extensively these figures hide the fact that the small firms that do undertake R&D tend to have high R&D intensities: almost 90% of the small firms that do R&D have intensities above 1%. Investigating how innovative effort varies with age of firm we find that the 1 to 2 year age cohort has the highest mean R&D intensity and the highest marketing intensity (Table 9). Similarly, this age cohort has the highest percentage of firms with high R&D intensity (defined as greater than 1%) (Table 10). These results conflict with the results from Figure 3, which showed that this cohort had the lowest proportion of innovators. This is an illustration of the potential differences between using the binary classification of the 'innovator' indicator and the innovation intensity measures.

The IBIS large firm database allows us to consider R&D intensity and also the number of applications for patents, trade marks and designs in 1996. Overall, the IBIS database suggests that around 12% of firms undertook some R&D. This compares with the GAPS figure of 16% for firms with over 100 employees. This implies that the IBIS database, which relies on a variety of sources for its data, does not completely cover the extent of R&D activity. The IBIS R&D data allows us to confirm the fact (see in the GAPS data) that the distribution of R&D intensities is skewed to the right, with a relatively small number of firms having high intensities. This confirms the general intuition that only a few firms are highly active in innovation. It also provides a warning that the results of any regression analysis on innovation related issues may be sensitive to these high intensity firms. The IBIS R&D data also allows us to show that R&D intensities are volatile, with the highest R&D intensity firms often having the highest volatility. Confirmation of this result from other data sources is needed (the second and subsequent years of the GAPS will allows this). Understanding the reasons for this volatility is also a priority since it may imply firms have difficulty financing R&D.

The data on intellectual property (IP) applications for large firms in 1996 showed that trade marks were the most common type of IP applied for (almost 18% of firms in the IBIS database applied for at least one trade mark). Again, we also find that trade mark activity varies dramatically across industries, with the proportion of firms applying for a trade marks varying between 5% and 70%. The percentage of all firms in the IBIS database that undertake either R&D or applied for at least one intellectual property right (in 1996) is 26%. This is the same percentage as the proportion of large firms in the GAPS that made at least one innovation.

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